MiniTarget for Quality Control in Newspaper Printing

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ABSTRACT

Running a printing press requires frequent measurements in order to achieve and maintain an acceptable level of print quality. Ideally, on-line measurements should be made and automatically used to adjust the inking system to achieve and maintain the desired target values. However, there are still several obstacles to this approach. As an intermediate solution, we have developed a system for quality control in newspaper printing, consisting of a miniaturized target, denoted in the following as MiniTarget, an optical device, and a three-chip CCD camera. The measurements are done off-line by a single shot. Individual prints are analyzed from which the behavior of the printing press can also be studied.

The MiniTarget was minimized to approximately 0.8 cm^2, which is more than a magnitude smaller compared to control strips commonly used. The MiniTarget contains areas of solid tone and halftone, lines for register control, and elements for doubling and slurring. Due to its small dimensions it is accepted in newspaper printing. The CCD camera is a commercially available three-chip 8-bit camera. Using the camera and image analysis software that has been developed, we measure registration, solid-tone density, dot gain, doubling and slurring, and colorimetric values. A measurement is made by capturing the image of the test target in a single shot followed by image analysis.

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1. INTRODUCTION

The demands of customers for more color and higher print quality are putting increased pressure on printers to improve not only the quality of printed products, but also the efficiency with which they are produced. To achieve such levels of print quality, methods to evaluate and control the important variables of the printing process, such as solid ink density, registration, grey balance, dot gain are of importance. In order to guarantee this print quality, methods to measure and quantify single prints, and methods to study the long-term behavior of a printing press must be developed.

In the various branches of printing (newspaper, commercial) the allocation of advertising space or extra paper for the use of control elements, is not desirable. Measurements of the important process variables would ideally be performed on-line from within the image, providing information for closed-loop control of the printing press. For such a system to meet both technical demands and financial constraints, the system would be required to measure accurately several quality attributes simultaneously, quickly, and from a minimum number of sensors. Due to the difficulties involved, no such system is currently available. Investigations into such a press control system have indicated that it is possible to measure densitometric attributes and colorimetric values from within a range of image types [1-4]. However, registration accuracy was not found to be acceptable unless optimal measurement locations can been found. Currently, independent solutions can be found for closed-loop measurement and control of the color registration and densities. Due to the limitations described above, an intermediate solution designed for newspaper printing has been developed, which allows off-line measurements of registration, densitometric, and colorimetric values, using a three chip CCD camera and a miniature test target.

2. PATCH DESCRIPTION

The dimensions of the MiniTarget are 10 x 7.5 mm^2. The target consists of 4 horizontal and 5 vertical lines and 12 different color patches (Fig. 1). Due to its small size it can be included inconspicuously into the layout of the page without demanding a lot of extra space.

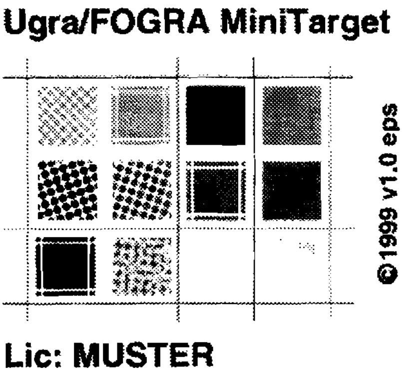

Fig. 1: The MiniTarget.
Its dimensions are 10 x 7.5 mm². This is a reduction of a magnitude compared to control strips commonly used.

Color registration measurements are made on four vertical and horizontal lines (one for each ink) located at specific distances from a reference line. By measuring the distance from the reference line to that of the color being evaluated, the color registration error is obtained. To measure accurately the distances between the printed lines, the magnification must be known. This can automatically be determined by adding a further line. Without any misregistration the lines are centered in a 0.4 mm white zone. For registration errors within ± 0.2 mm the lines and patches are well separated. Larger errors can easily be recognized visually and have to be corrected during printing.

To measure solid ink densities of the primaries (cyan, magenta, yellow, and black), for each ink one solid tone patch is required (four patches). Dot area and dot gain are calculated from the solid ink density, and the density of the halftone patch, typically measured at 50 % nominal dot area. Therefore four additional patches are needed. Trapping measurements require overprints of two colors in solid-tone or halftone (red, green, and blue). A three-color neutral grey patch is also included.
Therefore, to monitor the mentioned variables 12 patches are required. The size of each patch is 1.6 x 1.6 mm². This size is quite small, but guarantees a sufficient number of printed tints to be analyzed in order to minimize effects originating from single dots or phenomena from the paper.

Doubling and slurring are detected from the vertical and horizontal white zones within the CMYK solid tone patches, by evaluating the extent to which the width of the white zones has been reduced.

3. EXPERIMENTAL

3.1. EXPERIMENTAL SET-UP

A standard three-chip 8-bit CCD camera (SONY DXC-950P) is mounted onto an optical microscope (Fig. 2). After positioning the MiniTarget under the microscope a measurement is performed by capturing the image of the target in one shot followed by image analysis.

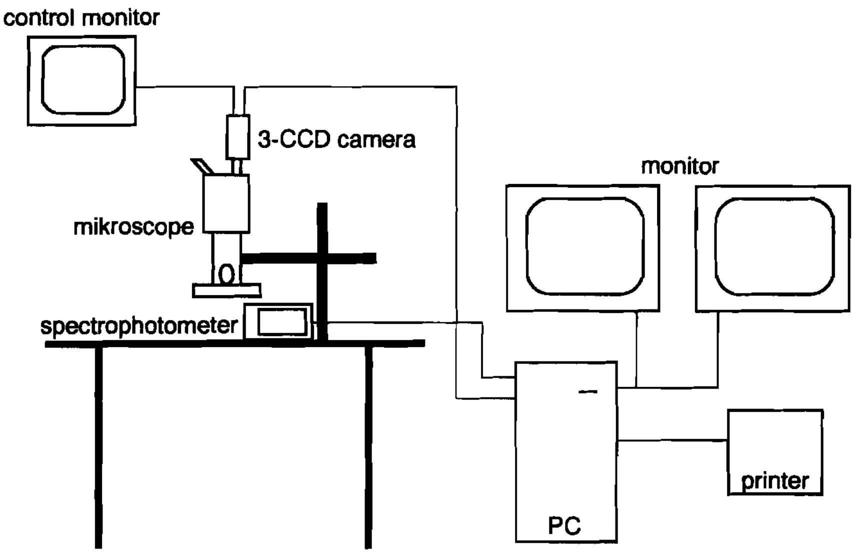

Fig. 2: Experimental Set-up
The measurements are made off-line.

To validate the system, a traditional test target was also printed and analyzed using a spectrophotometer. The traditional target (Fig. 3) contains the same patches included in the MiniTarget, plus additional eight patches for calculating doubling and slurring.

3.2. TEST SET GENERATION

In different newspapers both control elements were printed in several press runs. Both elements were placed in the same inking zone one below the other, so differences originating from the printing process could be kept to a minimum. A

traditional control element was measured using a spectrophotometer Gretag SPM 100-II. Solid ink density, halftone density, as well as CIEL*a*b* values were determined.
Due to the small size of the color patches of the MiniTarget, densitometric and colorimetric measurements cannot be performed by means of any traditional color measuring instrument. In the following we assume therefore that the two test elements have been printed with the same densities, and have identical CIEL*a*b* values.

For automatic color registration systems CCD cameras are commonly used. The results of the registration measurements made on the MiniTarget were compared with those obtained using the method described by Dätwyler [5] applied to the register cross also shown in Fig. 3.

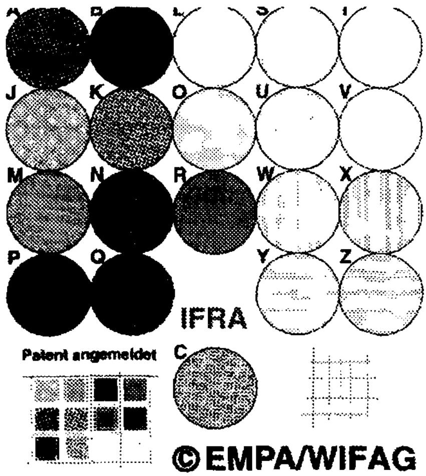

Fig. 3: The new MiniTarget (below) and a traditional target (above) were printed and analyzed. The measurements carried out on the traditional target served as reference values.

3.3. CALIBRATION

Due to different spectral response functions of the camera compared to standard densitometers or colorimeters, the RGB signals of the camera have to be converted to densities and to color values. Different techniques are discussed in literature [6-12].

The most simple and direct method for densitometric measurements is to measure the printed colors (CMY) through the complementary filter of the camera.
Color transformations are mostly performed by a polynomial approach. Polynomial transformations are simple requiring only measurements of XYZ tristimulus values and the corresponding RGB values for some number of color patches. A transformation matrix is obtained that provides best agreement between the two measurements.
Another analytical approach was first proposed by Viggiano *et al.* [12], modified by Brydges *et al.* [7] and Künzli [13]. They suggested measuring the spectra of a number of color patches followed by Principal Component Analysis. The Principal Component Analysis leads to a set of basis spectra, so that all original spectra can be reconstructed as a linear combination of this base. Using the basis spectra and the spectra of the calibration patches the weighting factors are determined. The same color patches are then analyzed with the CCD camera.
In this work we have chosen this approach. Additionally we transformed the RGB signals into RGB reflectance, which then were related to the weighting factors via a linear transformation.
Once the calibration is done, a spectrum can be predicted by measuring the RGB values. Predicting a spectrum enables one to determine tristimulus and densitometric values by applying the appropriate filters to the calculated spectrum.

4. RESULTS AND DISCUSSION

It should be pointed out, that the results presented, are achieved by comparing measurements carried out using a spectrophotometer on commonly used test targets, to measurements obtained by using a CCD camera on the MiniTarget. Therefore, all numbers are in terms of differences in density (ΔDensity), differences in CIE$L^*a^*b^*$ coordinates (ΔE^*_{ab}), mean values, or standard deviations.

4.1. REGISTRATION

It has been shown in the literature [5], that automatic color registration systems utilizing CCD cameras can be used to measure registration within an accuracy of $\leq 20\ \mu m$ [5]. To achieve this accuracy, a color calibration must be performed prior to making measurements. In addition to the color calibration, the resolution of the camera plays an important role. The resolution of the camera limits the accuracy of color registration measurements. In reference [5] an error of one pixel in the camera leads to a deviation of 5 μm. For color registration using the MiniTarget, an error of one camera pixel results in a deviation of 8 μm. The algorithm for color registration using the MiniTarget is insensitive to color changes, and therefore no color calibration has to be done.

A comparison of the two color registration systems showed a mean difference of 10 μm [14]. The deviations are color dependent. The differences are increased in yellow. We believe that the algorithm used for the MiniTarget is more accurate than the algorithm used for the reference measurements due to the sensitivity of the color calibration in the reference measurements. Thus, the accuracy of color registration measurements in the MiniTarget is expected to be $\leq$ 25 μm.
For the following discussion we measured 90 samples originating from 4 different printing houses. Altogether we considered 1140 measurements for color deviation, as well as 90 deviations for solid ink density and 90 measurements for halftone tone density deviations for each ink (total 720 density measurements).

4.2. DENSITOMETRIC

In Table 1 the mean deviations in density measurements (solid ink and halftone densities) ΔD are shown. One realizes that the mean density deviations are always negative indicating the density measurements using the MiniTarget and the camera are coming out to low. Density measurements using the camera on the MiniTarget show a small systematic error. The mean errors are color dependent and are between -0.029 $\leq \Delta$D $\leq$ -0.008.

	C	M	Y	K
Mean ΔD	-0.029	-0.008	-0.016	-0.020
σ	0.023	0.027	0.036	0.033

Table 1: Mean and standard deviation of solid ink and halftone densities.

Systematic errors are easily to correct. Beside the systematic error, we observe a frequency distribution in ΔD of individual measurements (Fig. 4). The ΔD differences for each color is about gaussian distributed. The standard deviations are in the range of 0.03.

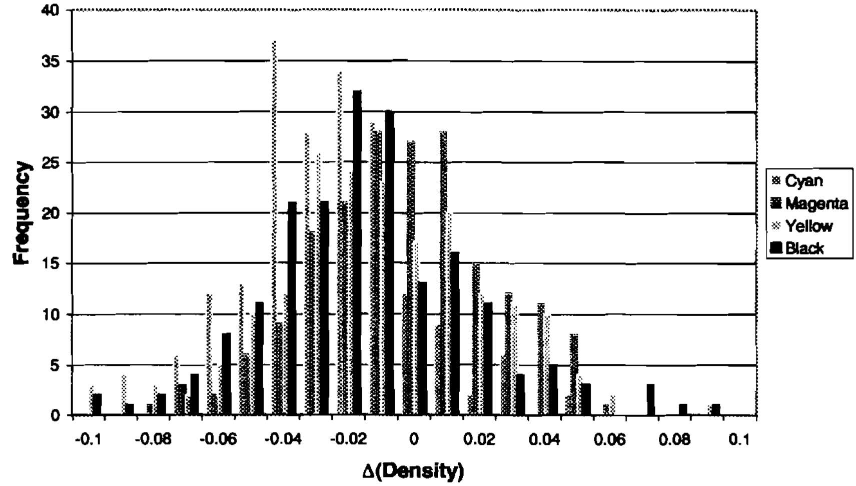

Fig. 4: Frequency distribution of ΔD deviations of individual measurements. Beside a color dependent systematic error we observe a quite broad distribution.

Within ± 0.03 density units are about 75% of individual density measurements.

Approximately 75% of the individual measurements are within an accuracy of ± 0.03 density units (taken from mean ΔD). This seems to be a quite wide range, if we consider that printers start to regulate the inking feed for density deviations more than 0.1 compared to the aim value. On the other side density variations of ± 0.03 are quite normal within an inking zone.

The dot gain calculations are influenced by the errors in the density measurements. The values typically varied in the range of 3 %. Doubling and slurring occurred in two press runs, and were also be detected using the MiniTarget.

4.3. COLORIMETRIC

A small systematic error could also be observed in the color measurements. For the 1140 measurements a systematic errors of $\Delta\overline{E}_{ab} = 0.67$[i] could be find. This small systematic error can be neglected for color measurements.

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[i] For clarity: $\Delta\overline{E}_{ab} = \sqrt{(\Delta\overline{L})^2 + (\Delta\overline{a})^2 + (\Delta\overline{b})^2}$

Looking at the ΔE^*_{ab} distribution of individual measurements (Fig. 5) we recognize that most of the colorimetric measurements show a difference of ΔE^*_{ab} = 2.5. More than 95% of the colorimetric measurements determined with the camera are within a deviation of $\Delta E^*_{ab} \leq 4.5$. The mean deviation of all individual ΔE^*_{ab} differences amounts $\overline{\Delta E_{ab}} = 2.4$ [ii], which is very good. The results for colorimetric measurements fulfil the needs in newspaper printing.

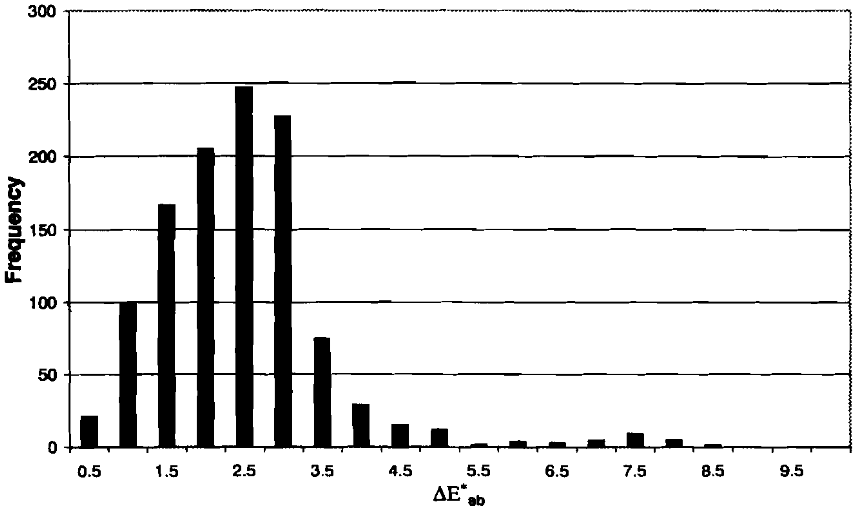

Fig. 5: Distribution of ΔE^*_{ab} deviations of single measurements. More than 95% of individual measurements are within $\Delta E^*_{ab} \leq 4.5$.

Some of the error may be due to printing inhomogenities between the MiniTarget and the large target, which we had assumed to be identical. Methods to accurately compare the color patches of both targets have to be evaluated.

5. OUTLOOK

Another important aspect is to save all measured values in a database. This allows:

- to obtain data for quality control and to document them

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ii $\overline{\Delta E_{ab}} = \sqrt{\sum_i \frac{\Delta E^i_{ab}}{n}}$

- to relate other parameters of the printing process (paper, ink etc) to the printing quality
- to study the long-term behavior of the printing press.

Currently all measurements are made off-line using an equipment optimized for the laboratory. However, for a system to achieve it's full potential and meet the increased demands for higher print quality, the system must be operated at the printing press. A hardware manufacturer is currently designing an easy to use handheld device (Fig. 6), which is announced for Drupa 2000.

Fig. 6: Prototype of an easy to use handheld device.
The device will be placed on top of the MiniTarget. A measurement is carried out by pushing a button. The results will be shown on the computer screen.

The MiniTarget can be downloaded as an eps-file from our homepage for free. http://www.ugra.ch.

6. SUMMARY

We have introduced a MiniTarget, which can be included into the layout of a newspaper, inconspicuously. In combination with a CCD camera it makes it possible to measure register, solid-tone density, dot gain, and colorimetric values. All measurements are done with a single shot.

The accuracy of color registration measurements is about 25 μm. The accuracy in densities is in the range of $\pm$ 0.03, which is quite good, and more than 95% of the colorimetric measurements are within $\Delta E^*_{ab} \leq 4.5$. The system fulfils the needs for newspaper printing.
The results demonstrate that the system is a powerful tool for quality control in newspaper printing.

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